Deciding within a competition

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Abstract

In this paper we present two models for the description of what we call a **decision within a competition**. With this term we denote an iterative process through which two sets of deciders D_a and D_b may take a decision about either one or two competing projects.
Such a decision involves the approval of a project and such approval turns into the definition and the sharing of the sets of benefits and costs that derive to the deciders either from the single project or from the two competing projects.
In both models the main aim is the acceptance of a project from both sets of deciders through the devising of fair solutions and the sharing of benefits and costs among such sets of deciders.

Keywords: negotiation, competition, iterative decision processes

1 Introduction

In this paper we present two models for the description of what we call a **decision within a competition**. With this term we denote an iterative process through which two sets of deciders[1] D_a and D_b may take a **decision** about either one or two competing projects. The aim of the decision is the approval of one project through its comparison with either the status quo (in the single project case) or with another project (in the two projects case).
Such a decision is a two steps process and involves (as a first step) the definition and (as a second step) the sharing of the sets of benefits and costs

[1]We use this term instead of "decision maker" to translate the Italian word "decisore" essentially for a reason of personal taste.

that accrue to the deciders either from a single project or from one of the two competing projects.
In both the aforesaid models the main aim is the acceptance of a project from both sets of deciders through the devising of fair solutions and the sharing of benefits and costs between the groups of deciders.
The paper is structured as follows.
It opens with some comments on both the decision and the negotiation processes then it goes on with an analysis of the various types of actors[2] (deciders, experts and stakeholders) and their interactions. At this level we show how each group of deciders may be replaced, under certain hypotheses, with the so called representative player so to bring the analysis back to the interaction of two players to which we can apply classical results from both Game Theory ([16]) and Negotiation Theory ([19]).
The next step is the presentation of the two models of decision within a competition. In the single project model we have a competition around a single project that has both supporters and opponents whereas in the two projects model we have two competing projects each with its supporters and its opponents. We note how the second model could be used for more than two competing projects (and so with more than two competing groups of deciders) through the adoption of simple extensions.
The presentation aims at the description of the structure of the processes and of their properties.
One of the key points of this part of the paper could be represented by the use of System Dynamics as a cognitive tool for the analysis of the [competing] project[s] ([2]). Such an analysis is not carried out in the present paper owing to space constraints. In order to understand this we should step back to the sets of the deciders D_a and D_b with their inner structures so to abandon the simplifications we have introduced with the adoption of the equivalent players.
In the closing sections we briefly discuss some possible extensions and present partial conclusions and guidelines for future researches.

2 The nature of the proposed approach

Our approach is mainly of **descriptive** type and at **high** or **abstract** level.

[2]An actor is a generic entity with the capability of performing actions and taking decisions. We are going to specialize it in the paper through the definition of different categories of actors. In the paper we may use that term to denote a generic member of such categories and as a synonym of the term player as it is used in Game Theory.

We adopt a **high level approach** since we are not interested in a fine grained and detailed description of the interactions among the actors but rather we are interested at providing the general framework within which such **goal driven interactions** occur. The interaction is goal driven since the involved deciders have a goal to reach that is the approval of a project and the consequent sharing of the associated benefits and costs.
We decided to adopt a **descriptive approach** since we mainly aim at describing how things occur in real wold settings through the use of simplified models that try to capture the essential features of the systems and processes that represent our area of analysis.
The descriptive nature of our approach will be evident from the analysis of the procedures we are going to present in the following sections of the paper.
The other two competing approaches could have been:

- a **normative** approach;

- a **prescriptive** approach.

A **normative approach** is an approach that aims at the definition of how actors should behave in real wold settings through the definition of the sets of proper actions that the actors can carry out in order to satisfy some well defined rationality criteria. Within this approach the actors are usually assumed to know their possible actions and the associated outcomes (under the form of utility values) and are assumed to follow the rules of the game so to attain each his best outcome.
A **prescriptive approach** represents a further step of reduction of the possible actions from the actors since in this case the procedures aim at defining the actions that the actors must carry out in real wold settings in order to satisfy some well defined rationality criteria.
In order to compare the three approaches we can use a dialogic metaphor and say that:

- according to the **descriptive approach** the actors can make any question they like on condition of respecting some general rules that define the structure of their interactions;

- according to the **normative approach** the actors can make only the questions that belong to some predefined sets and on condition of respecting some general rules that define the structure of their interactions;

- according to the **prescriptive approach** the actors can make only well specified questions on condition of respecting some well specified rules that define the structure of their interactions.

In the present paper we disregard both the normative and the prescriptive approaches since they are too limiting for the actors. Moreover our aim is to provide only the general framework of the procedures that the actors can adopt in order to decide and negotiate within iterative procedures that allow them to reach agreements that guarantee them reciprocal advantages.
Within this perspective we do not aim at the definition of optimal solutions rather at the definition of satisfactory settlements.

3 Decision or negotiation

3.1 Introduction

The procedures that represent the core of this paper are based on the use of a succession of interleaved decision and negotiation phases: during a decision phase the deciders act in isolation so to define accurately their next proposals whereas during a negotiation phase they can compare such proposals in order reach a mutually beneficial agreement. Within this perspective, in section 3.2 we briefly present the main features of both a decision and a negotiation process and implicitly we sketch their main differences.
Then in section 3.3 we present the possible interactions between decision oriented and negotiation oriented steps within a multi step iterative process.
The aim of this presentation is both to describe the main features and to underline the main differences between the two types of processes but without carrying out a detailed description of each type. For what concerns the **decision process** we refer to [20] or [13] or [10] whereas our reference texts for the **negotiation process** are [19] and [23].

3.2 A description in a nutshell

A **decision process**, at least in its classical forms, is concerned with a single decider that has to perform a **selection** under certain **external circumstances**. As a single decider we usually mean a single person but we may also represent a group of people that act as a single entity since they have to make the same selection under the same external circumstances with the same goals and the same utility values in the various cases.
The selection is a one step process and is grounded on initial conditions and on the possible moves that a decider can make given such initial conditions. Each move corresponds to the choice of one elements from the set A of the available alternatives.
Such a set is assumed to be perfectly known to the decider before the decision

process begins and cannot be modified during the execution of the decision process itself.
After the decider has made his selection the external circumstances enter into play under the form of the elements of the set S of the so called **states of the world** and the decider obtains a utility from his selection depending on which state of the world becomes true.
Also the set S is assumed to be known by the decider though its structure may be a little bit complex.
We can describe the whole decision process as follows:

(1) the decider has his set A and selects $a \in A$;

(2) one of the members $s \in S$ occurs;

(3) the decider gets his utility from a in s.

It is easier to understand the finality of this process if we imagine the utilities of the decider as the consequences that derive him from his decision and assume that the decider has well defined preferences over such consequences.
The preferences of the decider express the fact that he:

(a) prefers a consequence that gives him a higher utility;

(b) is indifferent between two consequences that give him the same utility.

The case (a) is represented with a strict preference relation $\succ$ ([21]) that is both transitive and asymmetric and so defines a strict partial order.
The case (b) is represented with an indifference relation $\sim$ ([21]) hat is reflexive, symmetric and transitive or, in other words, is an equivalence relation that splits the set of the consequences in a certain number of equivalence classes.
The whole decision process depends on the nature of the set S so that we can define, depending on that nature, the following types of decision processes:

(1) decision under certainty;

(2) decision under risk;

(3) decision under uncertainty;

(4) decision in conditions of ignorance.

We speak of **decision under certainty** if the set S contains a single element so that every alternative has a single consequence and the decider prefers the consequence with the highest utility. If there is more than one consequence

with the same highest utility the decider can choose one of them at random since he is indifferent among them.
We speak of **decision under risk** ([16]) if the set S contains more than one element and the decider can assign to each element $s_i \in S$ a probability[3] π_i that is termed **objective** since it does not depend on the beliefs and the desires of the decider but is grounded on some features of the elements of the set S. In this case the values π_i are seen as exogenous to the decision process.
On the other hand we speak of **decision under uncertainty** ([16]) if the set S contains more than one element and the decider can assign to each element $s_i \in S$ a probability[4] π_i that is termed **subjective** since it depends on the beliefs and the desires of the decider. In this case the values π_i are seen as endogenous to the decision process as the result of a preliminary evaluation step from the decider.
In both the cases (2) and (3) if $u(a_j, s_i)$ denotes the utility for the decider from the alternative a_j if the state of the world s_i occurs we have that a decider, according to a classic approach, evaluates the **expected utility** for each alternative as:

$$U(a_j) = \sum_i \pi_i u(a_j, s_i) \tag{1}$$

According to this approach the decider selects the alternative $a_k \in A$ that gives him the highest **expected utility**. Other approaches (such as the maximin approach, [12]) are both possible and sensible but we do not consider them in this paper essentially owing to space constraints.
For the types (1), (2) and (3) we refer also to [12] as well to [13], the latter for a somewhat different approach.
Last but not least we speak of **decision in conditions of ignorance** ([6], [7]) if the decider is in one of the following situations[5]:

- he is not able to assess the subjective probability for the members of S,
- he is not able to define all the members of S.

In both cases the decider is unable to evaluate the values of the expected utility according to relation (1). The possible solutions include:

[3] Of course we have $\pi_i \geq 0$ and $\sum_i \pi_i = 1$.
[4] Of course we have also in this case $\pi_i \geq 0$ and $\sum_i \pi_i = 1$.
[5] We underline that no uncertainty and no ignorance is assigned to the set A that is assumed to be fully known to the decider though this is, in many cases, far from being true.

- the selection of the alternative that can be corrected with the lowest cost if the state of the world that occurs proves that selection as wrong or harmful;

- the selection of the alternative with the highest number of possible, though costly, corrections;

- the selection of the best (according to a maximin approach, for instance) alternative on the basis of the known states of the world.

For further details about this complex approach we refer to [6] and [7].
Classical decision theory sees the decisions taken by a decider in isolation as one separated from the others. This is only partially true since a decider usually takes his decisions within a succession.
If the decisions of such succession are **independent**[6] we can use the classical approach for every decision as we have already outlined before.
If the decisions of such succession are **dependent** they usually aim at a precise goal. In this case we can imagine that the decider starts in an initial state with a set of alternatives A_0 and every decision is a step. Any decision entails a selection that together with a state of the world defines a new set of alternatives on which a new decision is based and so on until the last decision is reached so that the last selection brings the decider to his goal. If the decider acts in condition of certainty he can use backward induction techniques to define the proper succession of selections that allow him to reach his goal from his initial state. Under conditions of risk or of uncertainty the adoption of such approach is more complex but can give some insight for the definition of the overall plan together with the use of forward induction techniques.
A **negotiation process**, at least in its classical form ([12]), concerns two actors and can be described as a buyer/seller relation.
Under this perspective the buyer has an upper bound b of the prices he is willing to pay whereas the seller has a lower bound s for the prices he is willing to accept. If $b < s$ there is no agreement space between the two actors whereas if $b \geq s$ we have an agreement space with a width equal to $s - b$ that can be exploited by the two actors possibly with the help of a mediator or through the authoritative intervention of an arbitrator ([19]).
Classical solutions to the negotiation problem in presence of two actors have been proposed by Nash ([12]) and Zeuthen ([12]) as well as by Kalai/Smorodinsky and Rubinstein ([16]).
The approaches proposed by both Nash and Kalai/Smorodinsky are based

[6] Two decisions are said to be **independent** if their order can be reversed without any problem otherwise they are said to be **dependent**.

on the definition of a minimal set of rationality axioms. The two approaches, indeed, differ for the adoption of only one different axiom but share three other axioms. According to Nash the solution of a negotiation process is a sharing between the two players that satisfies the axioms of efficiency, symmetry, linear invariance and independence from irrelevant alternatives. Such solution is an allocation that maximizes the so called Nash product of the differences of the individual allocations and the respective shares in the so called conflict point. Kalai/Smorodinsky replace Nash's last axiom with the axiom of individual monotonicity and define their solution. In both cases if the players are rational and follow the axioms the solution if found in only one step.
Rubinstain proposed a multi step procedure of proposals and counter proposals but also in this case rational players, by using classical techniques of Game Theory such as backward induction, can find a proper solution at the very first step. All these approach share this common requirement: the utility functions of the players as well as the structure of the game must be a common knowledge between the players but this requirement is hardly satisfied in practice. Moreover they work well only for two players and for the sharing of a single item, such as an amount of money or something roughly perfectly divisible like this.
Last but not least Zeuthen proposed an approach based on a succession of steps involving the two players either in turn or simultaneously. It can be proved (see [12]) that Zeuthen's model can be reduced to a two step process where the two players find the solution at the first step. Moreover such an approach can be proved to be equivalent to that of Nash and, together with the other approaches, is based on the same assumptions of common knowledge.
In presence of more than two actors ([17], [16]) it is possible to give a solution to a negotiation problem from different perspectives depending on the characteristics of the involved actors.
If we imagine one seller with many possible buyers we can model a negotiation for the allocation of one or more goods to those buyers through auction mechanisms ([14], [15]). In this case we assume that the seller as an imprecise knowledge of the willingness to pay of the single buyers otherwise he could set up the proper number of one-to-one relations with those with the higher willingness to pay and sell them his goods at the proper prices.
In other cases that cannot be dealt with under the paradigm one seller/many buyers but where there is anyway an asymmetry among the actors with one client and many servers we can adopt a Contract Net approach ([26]). In this case we have one actor that acts as a client and contact a set of actors in order to find a suitable server. All the actors that receive the request and

that have the proper capabilities provide their bids among which the client chooses the one that better satisfies his requirements.
Last but not least, if we have a symmetry among all the actors we can use the tools of the Cooperative Game Theory with transferable utilities ([17], [16]) such as the core and similar concepts or the Shapley value and related concepts that involve all the actors forming the so called grand coalition.
The tools of the former family generally define sets of allocations of a cardinal quantity V among the various actors of the grand coalition depending on their features and on their power. If we consider the core it may happen that it consists of an empty set. In this case the members of the grand coalitions cannot share the quantity V in a way that is satisfactory for all the sub-coalitions so that there exists sub-coalitions that are better off by acting independently.
The tools of the latter family generally define in a similar way a single allocation of the cardinal quantity V among the various actors depending on their features and on their power.
Such allocation can either prove stable or unstable. If it is unstable we have the same problems that we have seen for the tools of the former family but if it is stable it has the advantage of providing a single allocation among the members of the grand coalition.
We close here the analysis of the decision and the negotiation processes referring to the many cited references for further details.

3.3 Decide and negotiate

From the presentation we have made in section 3.2 it may seem that decision and negotiation have very little in common essentially because a decision process involves a single actor in isolation whereas in a negotiation process we have at least two actors that repeatedly interact through a series of proposals and counterproposals.
This is partially true since we can have decision without negotiation but during a negotiation process each actor must take some decisions in order to frame his proposals and to accept or refuse the corresponding counterproposals, at least within a framework that is based on such multi step processes.
We need, therefore, a way to describe the interleaving of decision and negotiation steps within an overall procedure through which the actors perform a negotiated selection of a mutually beneficial solution in order to share something that, in our cases, is represented by a set of benefits and a set of costs.
In order to attain this goal in this section we present the basic structure of some iterative procedures that represent the basic framework on which we base the procedures that we are going to introduce in sections 5.1 and 5.2.

Our perspective is the following:

- we have a decision step D that involves the various actors in a stand alone process;

- we have a negotiation step N where the actors interact among themselves.

In this case we have that D influences N that influences the following D and so on. The interaction may occur at a **single level** or at a **double level**.
In the **single level** case the actors negotiate at the same time **what to share** and **how to share it**.
In the **double level** case the actors have a first level where they negotiate what to share between themselves and a second level where they decide how to share it.
If they meet a failure at the first level they may enter a settlement phase (that involves a mediator, [19]) with three possible outcomes:

- a recovery from the first level since the actors agreed to revise what they are going to share;

- a recovery from the second level since the actors agreed to revise how to perform the sharing;

- a termination of the procedure since, notwithstanding the third party intervention, they were not able to find any agreement for carrying on the procedure.

If they meet a failure at the second level we assume that they decide to recover from the first level since if they are not able to agree on how to share something maybe a solution consists in a redefinition of what to share.
In what follows we are going to describe in some detail the procedure in both the single level case and the double level case.
The overall procedure breaks off in two cases:

- because the actors find an agreement that is satisfactory for both of them;

- because the actors decide that there is no more room for a negotiation, at least temporarily, so that they may recur to an outer intervention before breaking off definitively the overall procedure.

From what we have said up to now it should be clear that we are going to present to types of procedures:

- a single level procedure;
- a double level procedure.

The former procedure can be used both as an autonomous procedure and as a module, possibly with some modifications, within the double level procedure.
The **single level procedure** involves a succession of **decision** and **negotiation** phases and its structure is the following:

(0) *initialization*;

(1) while there is *no agreement* and *no time_out* do

  (1a) **decision**;

  (1b) **negotiation**;

(2) if *agreement* then end;

(3) if *time_out* then *go to settlement phase*; end;

(4) settlement phase:

  (4a) mediation phase;

  (4b) if mediation succeeder then go to (1) else exit

In order to make the procedure fully operational we have to define the following steps:

(0) initialization;

$(1a)$ decision;

$(1b)$ negotiation;

$(4a)$ mediation.

A preliminary step we have to make involves the introduction of some notations. We denote the deciders as d_a and d_b. We have that:

- d_a takes a decision Δ_a and makes a proposal p_a;
- d_b takes a decision Δ_b and makes a proposal p_b.

We have that (with $i \in \{a, b\}$):

- the decisions Δ_i are revealed only through the corresponding proposals p_i;

- if the two proposals are compatible the deciders reach an agreement otherwise, in absence of a *time_out*, the two deciders make a further decision, one independently from the other;

- we say that p_a is compatible with p_b if each decider is willing to accept the averaged proposal otherwise we say that p_a is incompatible with p_b.

In order to explain the last point, that represents the core of the proposed negotiation step, we assume a simplified approach and note what follows:

- p_a and p_b are expressed through quantitative dimensions on the same scale;

- p_a and p_b are expressed with two vectors of the same cardinality.;

Under these assumptions we can define the middle point of the segment (p_a, p_b) as follows:

$$\bar{p} = \frac{p_a + p_b}{2} \tag{2}$$

If both deciders accept $\bar{p}$ then we say that p_a and p_b are compatible otherwise we say that they are incompatible.
If, for instance, the objective is a sharing, in the simplest case we can have:

$$p_a = (60, 40)$$

$$p_b = (30, 70)$$

so that we have $\bar{p} = (45, 55)$.
At the step $(1a)$ the two deciders take their decisions, one independently from the other, so to take into considerations their interests, their needs and the past steps, if any has occurred.
As to step $(1b)$ we can characterize it as follows:

- p_a and p_b are revealed simultaneously by the players;

- if $p_a \sim p_b$ then we have $\bar{p}$ as an agreement;

- if $p_a \nsim p_b$ then

  - d_a and d_b decide that they can go on so go to (1);
  - d_a and d_b decide that they need a third party help so that they trigger the *time_out* condition; go to (1);

where $\sim$ denotes a compatibility relation (in practice an equivalence relation). The *initialization* step is a preliminary step that accounts for the following two possible cases:

(A) sequential-simultaneous;

(B) fully simultaneous.

In the case (A) we have, for instance, that at step (0) d_a has taken a decision Δ_a so that he expresses a proposal p_a to d_b. In this case the procedure opens with a sequential step so that d_b knows the proposal made by d_a, has to take a decision and make his own proposal p_b. If $p_a \sim p_b$ then there is an agreement and the cycle ends with a success at the very first execution otherwise the procedure goes on as for the case (B), that we are going to examine shortly. In the case (B) we have, on the other hand, that step (0) is empty so that we have, at each step:

- two decisions Δ_a and Δ_b are simultaneously taken by the deciders at the step $(1a)$;

- two proposals p_a and p_b are simultaneously revealed at the step $(1b)$;

- once p_a and p_b have been revealed the procedure goes on as we have already seen before in the characterization of the step $(1b)$.

The procedure enters in the step $(4a)$ (*negotiation*) only if d_a and d_b feel the need of a third party intervention under the form of a mediator ([19]). The mediator is assumed to help the deciders to clarify their respective positions so that they are able to decide if they want to resume the whole procedure or if they think there is no possibility of recovery. In this latter case the deciders think that the procedure must be interrupted and the decision taken in some other way, possibly with the intervention of an arbitration. We note how the intervention of an arbitration may be implemented either through the intervention of a single decider that acts as an arbiter or trough a voting procedure that requires the intervention of many other actors and the use of complex mechanisms.
As a last comment we note how, in the single procedure case, we may have the following possibilities:

- the two deciders decide what to share and how to share it at the same time;

- what must be shared is fixed so the two deciders decide only how to share it;

- how to share something is fixed (for instance as percentages) so that the two deciders have to decide only what to share.

The last two possibilities are used in the double level procedure case.
In this case we, indeed, have that:

- at the first level, L_1, d_a and d_b decide what to share;
- at the second level, L_2, d_a and d_b decide how to share that what.

At both levels the deciders use the single level procedure as an ancillary procedure with some obvious modifications, as it will be evident from the applications we are going to present in the next sections of this paper.
At each step of this more complex procedure a **decision** may involve:

- the framing of what or how;
- the acceptance or the refusal of a proposal.

In a similar way a **negotiation** may involve the revelation of simultaneous proposals and the evaluation of their level of compatibility as an yes/no measure.
After all these premises we may define the framework of the double level procedure as follows:

$L1$ d_a and d_b decide and negotiate what;

if they agree then

$L2$ d_a and d_b decide and negotiate how;
if they agree then end with success;
else go to L1;

else

enter outer mediation phase;
if it succeeds on what then go to L1;
if it succeeds on how then go to L2;
if it fails then exit;

end;

At the steps $L1$ and $L2$, as we have already seen, the two deciders undertake a succession of alternate decision and negotiation phases. We have two such successions and each succession forms a cycle that may end either with a success or with a [partial] failure, each outcome giving origin to a further evolution that may even entail the reopening of one of the two levels of the overall procedure.

4 The various involved actors

4.1 Introduction

In this section we define more formally the notion of **actor** and specialize it, according to the roles that the various actors can play, through the definition of the following categories:

(1) the category of the deciders;

(2) the category of the stakeholders;

(3) the category of the experts.

The term **actor** denotes any entity that can play an active role in a process in the following ways:

- can define, at least partially, the steps of the process, their succession and their relations;
- can define, at least partially, the timings of the process;
- can define, at least partially, the termination conditions of the process;
- can react at least at some steps of the process and influence both their succession and their timings;
- can be involved to provide advice and expertise both at the level of structuring the process and during the process itself.

From the foregoing list it is possible to identify the features that characterize each of the foregoing categories though, as will be shown in section 4.2, they do not constitute a partition of the set of the actors but rather a covering[7].

4.2 Deciders, experts and stakeholders

In both the models that we present in this paper we are interested in the interactions:

- among deciders,
- among deciders and stakeholders.

[7] A **partition** of a set A is a set of disjoint subsets $A_i \subset A$ whose union is A whereas if we relax the requirement that the subsets are disjoint we get a **covering**.

usually with the intervention of "specialized actors" that we call **experts**. Roughly speaking we can state that:

- the **deciders** are those actors that have the deliberative and decisional power within a decision process;

- the **stakeholders** represent the people either positively or negatively affected by the decisions undertaken by the deciders.

We remark that the distinction between the categories of the deciders and the stakeholders is rather fuzzy and depends heavily on the problem we are dealing with. This means that an **actor** may play the role of a **decider** or the role of a **stakeholder** or both roles in a problem dependent way.
Within our framework we consider the informal diffuse expertise as a patrimony of the stakeholders. Such type of expertise, though not formalized, reflects the stakeholders' knowledge of the environment, its critical points, its weaknesses and its chronic and/or recurring problems.
Both informal and formal (to be defined shortly) knowledge play a distinct and relevant role in the construction of the models of the systems for the devising of the proper policies (see for instance [25] and [24]).
In addition to these two sets we can introduce the set E of the so called **experts**.
Experts are actors that bring their formalized knowledge (as recognized by the academia or by professional organizations) within the decision process and can belong both to the set of the stakeholders and to the set of the deciders.
This distinction is really important since the common background does not prevent experts from expressing divergent considerations on the same issue[8] depending on the set to which they belong. In this way we express the fact that the experts are **partisans** and not **neutral** though they often pretend to express neutral opinions and knowledge.
If D denotes the set of the deciders and S the set of the stakeholders we can have one of the following situations (see Figure 1):

(1) $D \cap S = \emptyset$ so that the two categories are disjoint sets,

(2) $D \cap S \neq \emptyset$ so that the two categories have common elements.

In the case (1) (see Figure 1 (c)) deciders and stakeholders are disjoint sets whereas the set E is supposed to be partitioned in the two sets:

[8]With this term we denote an object of a decision process to which we associate sets of benefits and costs.

- $E' \subset D$,

- $E'' \subset S$.

The case (2) turns into the two cases (a) and (b) of Figure 1.
In the case (a) all the deciders are also stakeholders but not vice versa whereas experts can be either deciders (and therefore also stakeholders) or stakeholders only. This is the case where a local community must decide about a local problem so that the deciders are the local administrators (that belong to the community) and experts are local experts (that belong to the community too).

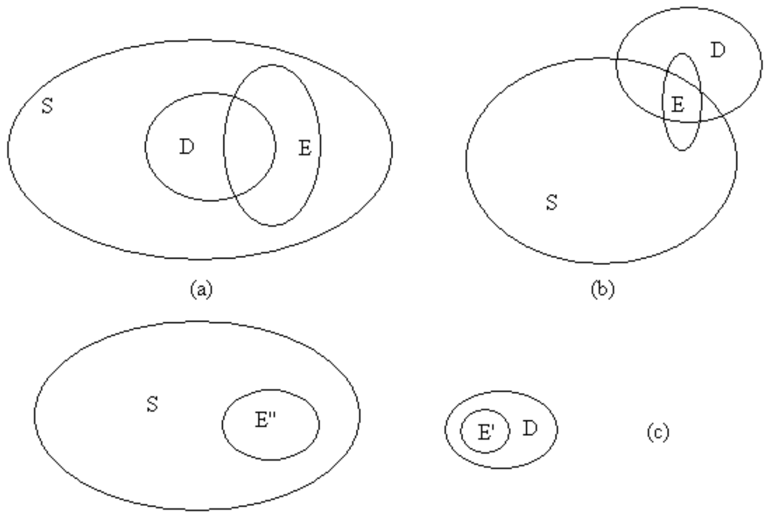

Figure 1: *Some of the possible relations between D, S and E*

In the case (b) the deciders may be also stakeholders or not and the same is true also for the experts.
This case is similar to the foregoing case where also non local deciders and experts are involved in the decision.
We remark how so far we have analyzed the sets D, E and S and their relations as if these sets were monolithic and homogeneous entities.
In real cases whenever a problematic issue needs to be solved the sets D, E and S split in subsets that we may imagine as disjoint for simplicity.
We, indeed, can imagine the two following situations:

(s_1) for the solution of a problem a project[9] p is proposed,

[9]The term project is a synonym of the term issue.

(s_2) for the solution of a problem two competing projects p_1 and p_2 are proposed.

4.3 The single project case

In the case (s_1) we have:

- the set D splits in the two subsets of opponents D_o and supporters D_s;
- the set S splits in the subsets of those who think to have more to gain than to lose (S_+), those who think to have more to lose than to gain (S_-) and those who think they are in more or less perfect balance ($S_=$);
- the set E splits in deciders side (E_d) and stakeholders side (E_s) sets.

We remark how, usually, the various subsets tend to show very different degrees of involvement and activity.
The cases where the members of the set S_- are more active, visible and capable of making alternative proposals are common as well as those where the members of S_+ play more passive roles since they either believe hat "nothing will be done anyway" or the "the same old guys will be able to block it, whatever it may be".
The attitudes of the members of S_- are usually classified, by the members of D_s and their consultants (see further on), as a Nimby[10] syndrome ([9]) since, in order to diminish the significance of an **active refusal**[11] very frequently there is the tendency to classify it as pure matter of selfishness also discarding the alternative proposals that usually the members of S_- elaborate.
Practical examples may include:

- the proposal of upgrading an existing infrastructure (a railway line, a highway) rather than building a new and heavily impacting infrastructure;
- the proposal to adopt new policies (such as the adoption of a differentiated waste disposal) rather than the building of a new dump or a new incinerator together with the optimization of existing plants;

[10] The acronym means "not in my back yard" and is claimed to denote a refusal to accept something as bad and a parallel proposal to realize it in some other place so to get the benefits without paying any cost. A concurrent acronym, far less known, is "Pimby" or "please in my back yard" with an almost dual meaning.

[11] An **active refusal** is a refusal together with a counter proposal and therefore is grounded on criticism, elaboration and deliberation.

- the proposal to adopt energy saving policies and decentralized energy production plants based on renewable energies rather than building new big plants for energy production and/or import;

- the proposal to change modality of transportation by switching from the use of private cars to the use of means of transport by rail;

and many others.
As to $S_=$ we note how they usually represent the very majority and the game preserve of both supporters and opponents. Its members, indeed, can be pushed in both directions by either threatening them with major damages or wheedling them with further and unexpected benefits so to widen either the set S_- or the set S_+.

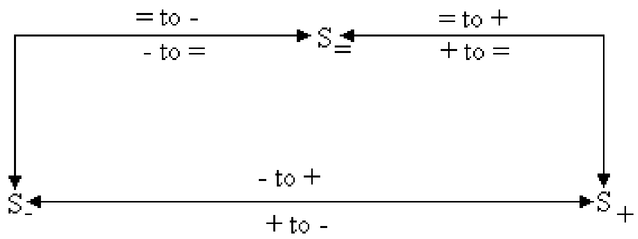

Figure 2: *Stakeholders' dynamics*

In Figure 2 we show the main possible dynamics of the stakeholders among these three sets.

(1) Neutral stakeholders become convinced to be negatively affected (denoted as $= to-$) and therefore become opponents and claim for compensations.

(2) Neutral stakeholders become convinced to be positively affected (denoted as $= to+$) and therefore become supporters and claim for rapid deliberation and implementation.

(3) Opponents lose interest (denoted as $-to =$) owing to the failure of their opposing actions.

(4) Supporters lose interest (denoted as $+to =$) owing to excessively long deliberation phases.

(5) Opponents get the requested compensations or modifications so to become supporters (denoted as $-to+$).

(6) Supporters become opponents after unwanted and unfavorable modifications (denoted as $+to-$).

We recall how such transitions involve subsets of the various sets and not necessarily whole sets so that the transactions define dynamic flows of stakeholders among the three sets S_-, S_+ and $S_=$.
The **experts**, on the other hand, usually play partisan roles (even in most of the cases where they claim to act objectively). They may be:

(ex_1) consultants of either D_s or D_o so to get a fee for their professional services.

(ex_2) supporters and possibly members of one of the stakeholder sets S_- or S_+ so to put at these stakeholders' disposal their professional expertise.

In the (ex_1) case they are usually formally hired by the parties to provide arguments either in favor or against the project p. In order to do that they tend to stress favorable (to their party) data, facts and external conditions and to minimize or to discard correspondingly unfavorable (to their party) items.
In the (ex_2) case they try to formalize according to recognized and accepted paradigms the either negative or positive perceptions that their associated stakeholders have of the project p and its consequences.
In both cases the experts' actions aim at:

- corroborating the thesis of their associated party;
- discrediting the thesis of the opposing party;
- acting on the members of $S_=$ so to push them among their supporters;
- acting on the supporters of the other party so to push them among their supporters.

All these actions tend to gain legitimation to and to increase the possibilities of one party against the other in view of an electoral competition where the stakeholders are called either to approve of or to reject the project p.
As to the **deciders** we note how they tend to form competing and conflicting parties: the party of the opponents D_o and party of the supporters D_s.
From this distinction we cannot derive the conclusion that the two parties are monolithic and homogeneous entities but rather we can imagine a continuum along which the deciders are distributed as a function of their resoluteness with regard to the project p.
The **deciders' resoluteness continuum** is shown in Figure 3 where we have:

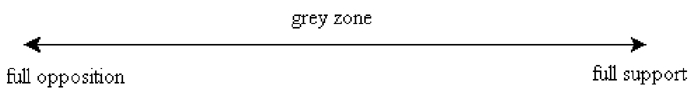

Figure 3: *Deciders' resoluteness continuum*

- on one side the area of those who make a full opposition and that almost surely and permanently belong to D_o;
- on the opposite side the area of those who give full support and that almost surely and permanently belong to D_s;
- in the middle a "grey zone" of deciders dynamically migrating from one set to the other depending on the current conditions.

The probability of migration tends to zero at both extremities and attains its maximum value in the middle of the continuum though we cannot define statically any distribution of the members of a given set D along the continuum.
If the two parties are highly polarized so that can be thought of as being both monolithic and homogeneous (see Figure 4) we can imagine that they are centered each around one of the extremes of the continuum so that the "grey zone" is empty. In this case we can easily replace each party with the so called **equivalent player**:

d_o for the party D_o,

d_s for the party D_s,

so that we can describe the strategic interaction either as a two players non co-operative game or as a two player negotiation depending on the hypotheses we set up to describe the interaction. If ([19] and [23]) the players are both fully rational and have a full knowledge of their strategic interaction we are in the realm of Non Co-operative Game Theory. If the two players are endowed with a bounded rationality we are in the realm of Negotiation Theory. The same holds if this "deficiency" affects only one of them.
In the present section we do not consider the case of the equivalent players and go on with the more general case of Figure 3.
Once all these sets have been defined and characterized we can try to define some relationships among them. Some of these relationships are quite obvious but others may be harder to ascertain and characterize.
To the category of the obvious relationships we can assign the following associations:

Figure 4: *Polarized deciders and equivalent players*

- D_o with S_- as allies with regard to the project p,
- D_s with S_+ as allies with regard to the project p.

The members of $S_=$, as we have already seen, can be pushed by the pressure of experts, deciders and other stakeholders to join either S_- or S_+ (persuasion).
To the category of the harder relationships we can assign the following associations:

- those of the experts of the set E to the deciders of either D_o or D_s;
- those of the experts of the set E to the stakeholders of either S_- or S_+;

since they depend largely either on economic motivations or on personal values and beliefs.

4.4 The two projects case

In the case (s_2) we have two competing projects p_1 and p_2 so that the interactions among and inside the sets D, E and S tend to become more complex.
To analyze the various possibilities from the **stakeholders' point of view** we use Table 1 where we represent the possible attitudes of the stakeholders of the set S with regard to the projects p_1 and p_2. We recall that the possible attitudes of the stakeholders are:

- an unfavorable attitude marked as $-$,
- a neutral attitude marked as $=$,
- a favorable attitude marked as $+$.

With these conventions, for instance, the case S_1 characterizes the stakeholders of a subset of S that are unfavorable both to p_1 and p_2 and therefore may be seen as strong supporters of the status quo (at least with regard to the

p_1, p_2	-	=	+
-	S_1	S_2	S_3
=	S_4	S_5	S_6
+	S_7	S_8	S_9

Table 1: *Attitudes of the stakeholders*

proposed projects). Similar considerations hold for all the other cases.
As to Table 1 we therefore have that each cell defines a subset of S as a function of the attitude of its members with regard to the projects p_1 and p_2. In this way we define a partition of the set S made of six disjoint subsets S_i $(i = 1, \ldots, 6)$ such that $\cup_{i=1}^{6} S_i = S$ and:

S_1 is the subset of the opponents to both p_1 and p_2 and so the strong supporters of the status quo (at least with regard to these competing projects);

S_2 is the subset of the weak opponents of p_1;

S_3 is the subset of the strong supporters of p_2;

S_4 is the subset of the weak opponents of p_2;

S_5 is the subset of the weak supporters of the status quo;

S_6 is the subset of the weak supporters of p_2;

S_7 is the subset of the strong supporters of p_1;

S_8 is the subset of the weak supporters of p_1;

S_9 is the subset of the strong opponents of the status quo.

In Figure 5 we show some of possible alliances (as dotted lines) between subsets of stakeholders as well as some possible migratory paths (with solid lines) and (with dashed lines) some "disenchantment" links.
Dotted undirected lines identify possibly bidirectional alliances between the two sets joined by such lines whereas dotted directed lines denote preferential alliances.
The preferential alliances involve only some of the pairs and prevent the "alliance relation" from being transitive (otherwise we could have, for instance, the members of S_3 allied with those of S_7 a rather nonsensical situation). The lack of transitivity is a consequence of the nature of the subsets which

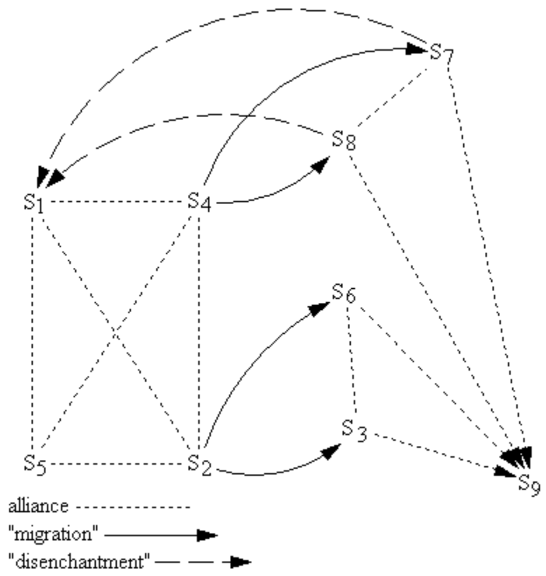

Figure 5: *Possible interactions among subsets of stakeholders*

are put in relation by the relation itself.
Solid directed directed arcs, on the other hand, identify some of the possible migration links of the stakeholders in absence of an alliance:

- members of S_4 (weak opponents of p_2) may migrate among the members of either S_8 or S_7 so to become more or less active supporters of the competing project p_1;

- members of S_2 (weak opponents of p_1) may migrate among the members of either S_6 or S_3 so to become more or less active supporters of the competing project p_2.

Dashed lines identify inverse migrations caused by:

- a loss of interest in a project,

- a loss of trust in the capability of the deciders to realize that project,

- a loss of trust in the possibilities to oppose to a project,

so that stakeholders retreat on more neutral and disenchanted positions.
In Figure 5 we represent only a small subset of the possible "disenchantment" links. Other links may involve a passage from either S_8 or S_7 to S_5 as well as a passage from either S_3 or S_6 to either S_5 or S_1.

We note how the links representing alliances may provide the stakeholders with migration paths between the sets S_i. In this way we can, for instance, imagine a migration path of the form $S_1 \longrightarrow S_2 \longrightarrow S_6$ with a possible extension to S_9 but many more of such paths can be devised so to characterize the dynamics of the stakeholders among the various subsets S_i. This dynamics depends on the fact that the stakes of the stakeholders change with time and are affected by the delays of the decision process as well as by other features such as the pressure from other stakeholders and from the deciders of the sets D_1 and D_2.
Such migration paths may involve [simple] cycles that describe how the positions of the stakeholders change with time depending on the evolution of the political situation. For instance we can consider the cycle:

$$S_1 \rightarrow S_4 \rightarrow S_7 \rightarrow S_1 \tag{3}$$

that describes how some stakeholders may be slowly attracted by project p_1 and how such attraction may turn int a disenchantment if the deciders prove unable to implement that project.
At this point we have to say something about both the set of deciders D and the set of the experts E.

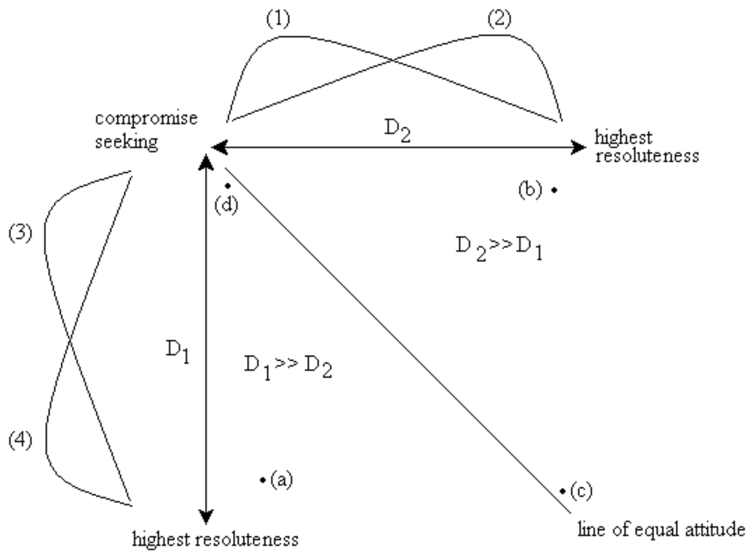

Figure 6: D_1*'s and* D_2*'s resoluteness continua*

For what concerns the **deciders** we can extend what we have seen in Figure 3 to the case of the two sets D_1 and D_2 (see Figure 6).
We recall that:

- the members of D_1 are the proponents of p_1 and are supposed to be, at least initially, the opponents of p_2,

- the members of D_2 are the proponents of p_2 and are supposed to be, at least initially, the opponents of p_1.

As Figure 6 shows the two sets do not represent monolithic and homogeneous entities but rather they contain members with a continuously varying degree of resoluteness.
In Figure 6 we define all the possible relations among the members of the deciders sets D_1 and D_2. Such relations depend heavily on the distributions of the deciders along the resoluteness continua. In Figure 6 we represent, for simplicity, only four paradigmatic distributions:

(1) members of D_2 are more compromise seeking;

(2) members of D_2 are more resolute;

(3) members of D_1 are more compromise seeking;

(4) members of D_1 are more resolute.

Such distributions must not be seen as statically defined but as representing extreme cases of dynamically varying distributions of the deciders during the decision process. We note that the number of the deciders that show a certain degree of resoluteness is given by the value of the distribution in that point so that the total area under each curve coincides with the cardinality of each set.
Usually at the very start the members of D_2 show a distribution like (2) whereas those of D_1 show a distribution like (4)[12]. Such distributions may change during the process, usually in a symmetric way, so that they may oscillate between the pairs of extremes we have listed before. If the two distributions tend to (1) and (3) this means that both groups recognize merits to the competing project and, therefore, are more willing to reach a compromise. Such acknowledgment of reciprocal merits may be reached through the use of formal methods such as those of the System Dynamics. In this paper we do not deal with such problems and refer to [22], [25], [24], [2], [3] for further details.
In Figure 6 we have also represented the so called "line of equal attitude" that identifies two zones:

$D_1 >> D_2$ where the members of D_1 show a more resolute attitude than those of D_2,

[12]In this case we make the simplifying assumption of continuous distributions.

$D_2 >> D_1$ where the members of D_2 show a more resolute attitude than those of D_1.

Every point in this bidimensional space identifies a group of deciders whose numerousness depends on the distributions of the deciders within the sets D_1 and D_2.
At the point (a), for instance, we have an interaction between resolute members of D_1 and compromise seeking members of D_2 where the former try to convince the latter to shift party.
At the point (b) we have a dual situation of the one at point (a).
At the point (c) we have an interaction between resolute deciders of the two sets. This interaction may have both negative and positive effects since it may either hamper the achievement of a compromise solution or it may bring to a confrontation from which one of the two competing projects p_1 and p_2 emerges as the winning solution.
At the point (d) we have an interaction between compromise seeking deciders of the two sets. This interaction may have both positive and negative effects since it may either facilitate the achievement of a compromise solution or it may hamper the decision process and the action of the more resolute deciders.
In all these cases the efficacy of the actions depends of the effective distributions of the deciders within the two sets D_1 and D_2.
In the case of the **experts** we may try to characterize them as we have made for the stakeholders so to classify their attitude with regard to the two competing projects p_1 and p_2 (see Table 2). For the classification of the experts we have used the same symbols we have used in Table 1 for the stakeholders.

p_1, p_2	-	=	+
-	E_1	E_2	E_3
=	E_4	E_5	E_6
+	E_7	E_8	E_9

Table 2: *Attitudes of the experts*

The subsets E_j ($j = 1, \ldots, 6$) can be described as we have done for the corresponding subsets S_i of S. In this case we have:

E_1 is the subset of the experts that oppose to both p_1 and p_2 and so the strong supporters of the status quo (at least with regard to these competing projects);

E_2 is the subset of the experts that weakly oppose to p_1;

E_3 is the subset of the experts that strongly support of p_2;

E_4 is the subset of the experts that the weak opponents of p_2;

E_5 is the subset of the experts that weakly support the status quo;

E_6 is the subset of the experts that weakly support p_2;

E_7 is the subset of the experts that strongly support p_1;

E_8 is the subset of the experts that weakly support p_1;

E_9 is the subset of the experts that strongly oppose to the status quo.

Using analogies between tables 1 and 2 we could as well devise a structure similar to that of Figure 5 also for the experts. In the case of the experts, however, we prefer to refer to Figure 7 where we introduce the following relations between subsets of experts:

- **dynamic relation**,
- "**convertion**",
- "**covering**".

In order to understand such relations we must consider that in the procedures the competing projects are examined one at a time so that they are implicitly and indirectly compared between themselves through the respective costs and benefits for the equivalent players. A **dynamic relation** represents a relation of mutual support between two subsets with the possible exchange of members from one set to the other and vice versa. It is a peer-to-peer relation.
A "**convertion**" denotes a shift of some experts from one subset to another. This shift may occur owing to technical or professional reasons.
The presence of a convertion between two subsets defines such subsets as opposing. From this we see how, for instance, E_3 and E_6 are opponents of E_2. This relation is not represented in Figure 7 in order to avoid the drawing of too many relations.
In Figure 7 for simplicity we represent only some of the possible convertions since similar convertions may occur also between the sets E_6 and E_1 and E_3 and E_1. We note that in this way we obtain a graph with cycles that account for the "migratory" nature of the experts among the various positions

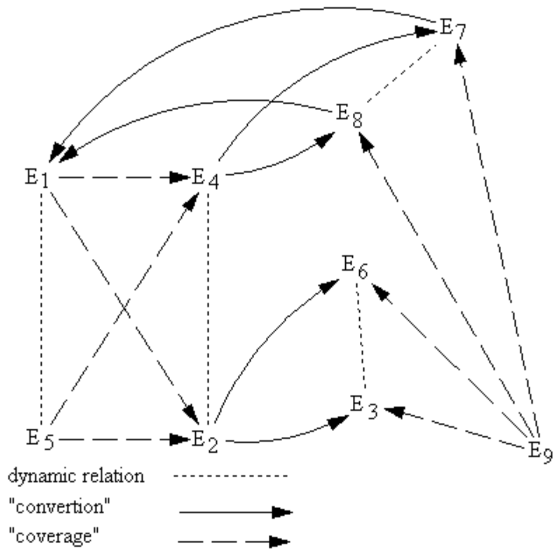

Figure 7: *Possible interactions among subsets of experts*

depending on the progress of the decision process. In the diagram of Figure 7 we have, for instance, the cycle:

$$E_1 \to E_4 \to E_8 \to E_1 \tag{4}$$

but many other cycles (also involving undirected links that represent dynamic relations) can be detected in that diagram. These cycles do not necessarily represent interested or malicious behaviors but rather they must be seen as expressions of strategic behaviors of the experts.
A "**covering**" identify an asymmetric relation between two subsets E_i and E_j according to which the members of the former may support those of the latter but the vice versa is not necessarily true. This support may take either a positive form (as arguments in favor) or a negative form (under the form of attacks to opposing groups such as E_2 as opponent of E_3 that is under the covering of E_9) and is provided thanks to that covering of interests and values.
The relation of opposition relation is extended by covering. With this we mean that E_3 and E_6 are opponents also of E_5 and E_1 owing to the presence of a covering between E_5 and E_2 and E_1 and E_2.
After having performed such a classification we can try to associate each subset E_i of the partition of the set E to one or more of the subsets of S and to either D_1 or D_2.
We remark how the **experts** E in real cases are inserted in one of the sub-

sets E_i on the ground of their public declarations and/or publications (on journals and books) in relation to the two competing projects p_1 and p_2. The analogous attribution of the stakeholders S can be carried out through polls, interviews and similar tools whereas:

- the deciders are assigned to one of the two parties/sets D_1 or D_2 depending on their political membership but also on the ground of their public declarations;

- within each set the deciders are distributed along the resoluteness continuum essentially on the ground of their public declarations.

The final step of this analysis is the definition and the characterization of the possible relations among the various (possibly empty) sets S_i and E_j (with $i, j = 1, \ldots, 9$) among themselves and with the sets of the deciders D_1 and D_2. For this purpose we may remark that:

- the sets E_j and S_i with $j = i$ are in a sort of a more or less formalized "alliance";

- we can imagine a relation of "**covering**" between some sets E_j and some sets S_i (for instance among E_5 and S_1, S_2 and S_4 or among E_9 and S_7 and S_3);

- the sets E_7, E_8, S_7 and S_8 can be seen as supporters of D_1;

- the sets E_3, E_6, S_3 and S_6 can be seen as supporters of D_2;

- the sets E_1, E_2, E_4, E_5, S_1, S_2, S_4 and S_5 can be seen as opponents of both D_1 and D_2;

- the main aim of the members of D_1 is to increase both E_7 and S_7 whereas the main aim of the members of D_2 is to increase both E_3 and S_3;

  the presence of the sets E_9 and S_9 may represent for the members of the sets D_1 and D_2 a bigger problem than the presence of their opponents because it can trigger a process leading to a stalemate between the concurrent projects (if, as it happens very often, they cannot be both implemented).

These relations may shed light on the dynamics through which groups that are in competition for the implementation of concurrent projects may either reach a compromise (or win-win) solution or a more classical win-lose solution.

5 Deciding within a competition

In this section we introduce and examine the following two situations:

(c1) a set of deciders D_a propose an issue i_a that, after its revelation, finds the opposition of another set of deciders D_b;

(c2) a set of deciders D_a proposes an issue i_a whereas another set of deciders D_b proposes a competing issue i_b.

In the case **(c1)** the proponents D_a of the issue i_a claim that it is characterized by the following features:

(c1a) a set of costs $C_a = \{C_{a_i} \mid i \in I\}$ to be shared between D_a and D_b as respectively the two sets C_1 and C_2;

(c1b) a set of benefits $B_a = \{B_{a_j} \mid j \in J\}$ to be shared between D_a and D_b as respectively the two sets B_1 and B_2.

They also claim that the benefits B_a outweigh the costs C_a according to certain performance criteria (such as a **Cost Benefit Analysis** or **Cost Effectiveness Analysis**, [10], or the like). In this case the members of D_b my reject either the proposal in full or the proposed sharing of costs and benefits by using any combination of the following argumentations:

(r1) by stating that the claimed costs C_a do not cover the real costs and that these are bigger (quantitative aspects) and/or worse (qualitative aspects);

(r2) by stating that the benefits B_a have been overestimated and that they are indeed lower and/or uncertain since they are based on fuzzy estimates;

(r3) by refusing the costs sharing C_1, C_2 as unacceptable;

(r4) by refusing the benefit sharing B_1, B_2 as unacceptable;

(r5) by contesting the adopted performance criteria as theoretically faulty or badly applied or wrongly evaluated in their conclusions.

As it will be shown later on (see section 5.1) $(r1)$ and $(r2)$ are well suited for the so called **coarse grain negotiation**[13], $(r3)$ and $(r4)$ are well suited

[13]The coarse grain negotiation corresponds to the negotiation about what to share whereas the fine grain negotiation corresponds to the negotiation about how to share what.

for the so called **fine grain negotiation** whereas $(r5)$ can be used in both cases.
In this case the focus is more on the sets C_a and B_a and their subsets rather than on the issue i_a itself so that the process may turn into a **negotiation** between D_a and D_b for the reduction and/or redistribution of the costs and an increase and/or redistribution of the benefits, see section 5.1.
In the case **(c2)** we have the following situation:

1. the members of D_a claim that i_a has costs C_a and benefits B_a to be shared between D_a and D_b as respectively the sets C_{a1}, C_{a2} and B_{a1}, B_{a2};

2. the members of D_b claim that i_b has costs C_b and benefits B_b to be shared between D_a and D_b as respectively the sets C_{b1}, C_{b2} and B_{b1}, B_{b2};

3. the members of D_a refuse i_b using arguments such as $(r1)$, $(r2)$, $(r3)$, $(r4)$ and $(r5)$;

4. the members of D_b refuse i_a using arguments such as $(r1)$, $(r2)$, $(r3)$, $(r4)$ and $(r5)$.

Again the focus is more on the sets of costs and benefits rather than on the two issues and this triggers a **double negotiation** that we examine in section 5.2.
In both cases we have a competition that can be described through negotiation procedures (section 5.1) or double negotiation procedures (section 5.2). The use of such procedures is based on the assumption that the sets D_a and D_b form stable coalitions so that there is no inter coalitions dynamics.
We may therefore consider each set as a single negotiator (the **representative** or **equivalent** player) discarding the ways in which the resulting benefits and costs are shared among the members of each coalition and so the intra coalition dynamics. From a more formal point of view we have the following cases:

- the members of each coalition signed binding agreements with penalties so that the denunciation is too costly to be carried out by single players or even by sub-coalitions;

- the members of a coalition have a non empty chore and so a stable sharing among the members of each coalition.

From these premises we consider:

- d_a as the equivalent player for the set D_a,

- d_b as the equivalent player for the set D_b.

5.1 Negotiation procedures

In this section we examine the case ($c1$) and its possible solutions through the use of negotiation procedures[14].

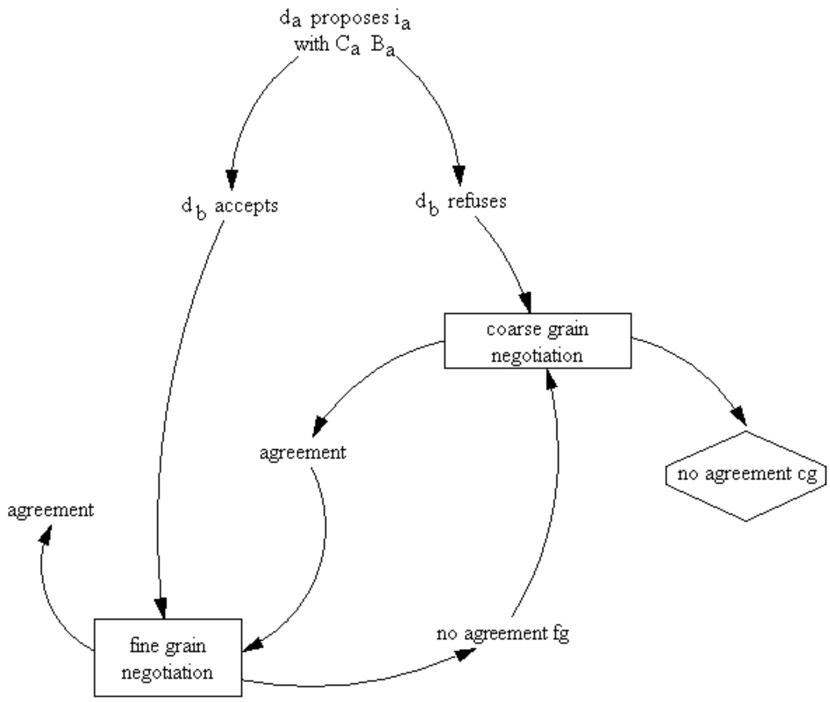

Figure 8: *Structure of the negotiation procedure*

As Figure 8[15] shows we have a procedure made of a sequence of steps where the the two [equivalent] players act on alternate phases or turns. The procedure opens with d_a presenting the issue i_a with the associated sets C_a and B_a.
At this point d_b may:

(1_a) refuse the proposal so that the procedure goes on with a **coarse grain negotiation** step;

[14]Both the fine grain negotiation and the coarse grain negotiation involve decision steps from both deciders.

[15]In the figure we use **cg** to denote **coarse grain** and **fg** to denote **fine grain**.

(1_b) accept the proposal so that the procedure jumps directly to the **fine grain negotiation** step.

The **coarse grain negotiation** step represents a complex and time consuming procedure, to be described shortly, through which both players try to reach an agreement about the composition of the sets C_a and B_a over which they are negotiating. This procedure aims at defining which are the costs and the benefits for both players.
On the other hand the **fine grain negotiation** step represents another complex procedure through which the two players try to agree on how the various elements of the sets C_a and B_a are to be shared between themselves so to define how costs and benefits should be shared between the two players.
In the case (1_a) the two players negotiate the composition of the sets C_a and B_a and:

($1'_a$) can reach an agreement so they switch to step (1_b);

($1''_a$) are not able to reach an agreement.

The case ($1''_a$) is represented by the hexagon of Figure 8 whereas the case ($1'_a$) is followed by a **fine grain negotiation** step.
If the **coarse grain negotiation** step fails the players can resort to the intervention of an outer **mediator** that may help them in a **mediation phase** (see Figure 9) that may either succeed or fail.
Also the **fine grain negotiation** step is a time consuming activity that may end either with an **agreement** or without **any agreement**.
In the **agreement** case the procedure is over and the two players know each own's fraction of every element of both C_a and B_a.
In the **no agreement** case the procedure goes back to **coarse grain negotiation** step since if the two players cannot agree on how to share certain items they must revise what to share.
The overall procedure has, therefore, three possible outcomes (see Figure 9):

(o_1) an **agreement** between d_a and d_b,

(o_2) the need to solve the **stalemate** represented by the lack of agreement at the coarse negotiation step,

(o_3) the **failure** of the mediation phase.

The outcome (o_1) represents a successful outcome of the procedure where the two players agree on what to share and how to share what between themselves. When the sharing has occurred the two coalitions must distribute what they got among their members. This sharing may be carried out using classical tools of Co-operative Game Theory under the hypothesis of inner stability of the two coalitions.

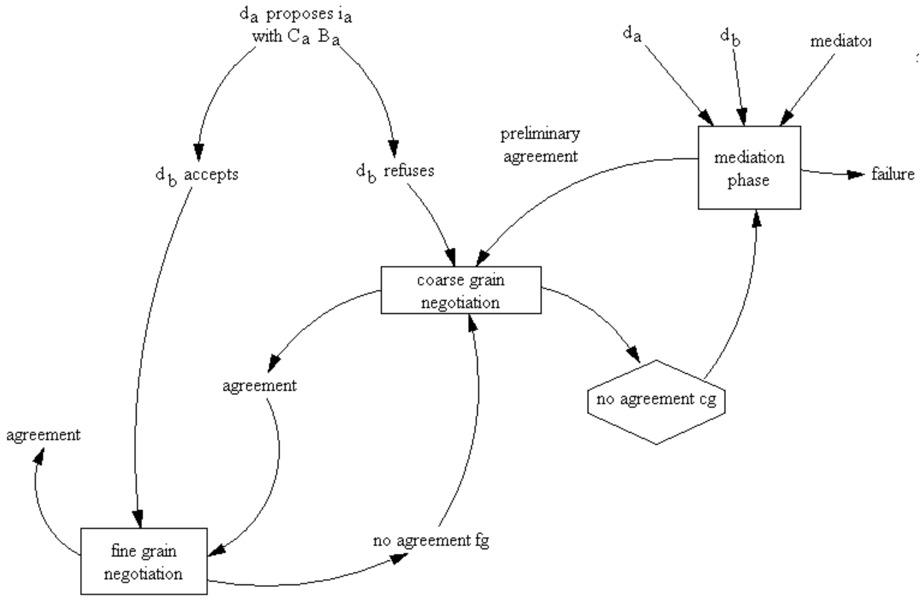

Figure 9: *Extended structure of the negotiation procedure*

The outcome (o_2) may require the intervention of an outer authority that acts as a mediator (see Figure 9) so to allow d_a and d_b to reach an agreement and reopen the coarse grain negotiation step. The agreement may even concern the taking into considerations other types of costs and benefits so to enlarge the sets C_a and B_a.
The outcome (o_3) represents the failure of the current negotiation phase and the description of its evolution is out of the scope of the present paper. We only note how either d_a or d_b or both can appeal to political or judicial authorities to defend their claims but can also resort to either a consultative or an abrogative referendum to strengthen their positions, one player against the other.
In this case we need to switch to a more complex model that entails the giving up of the equivalent players and both the consideration of the deciders as structured entities and the involvement of all the interested actors. The treatment of this model is fully out of the scope of this paper.
The **mediation phase** (see Figure 9) involves both players d_a and d_b and a **mediator** in a process through which the two players can reach a **preliminary agreement** on the structure of the sets C_a and B_a or declare that the mediation has failed. In the case of a preliminary agreement the negotiation

procedure is resumed from the **coarse grain negotiation** phase (see Figure 9).
The negotiation procedure therefore contains the two negotiation procedures that in Figure 8 are represented as square boxes. Their further analysis requires some preliminary steps.
As we ave already stated, issue i_a is associated to a set of costs C_a and to a set of benefits B_a. These two sets have the following inner structures:

$$C_a = \{C_{a_i} \mid i \in I\} \tag{5}$$

and:

$$B_a = \{B_{a_j} \mid j \in J\} \tag{6}$$

where I and J are index sets, subsets of the set $\mathbb{N}$. Every element of the set C_a (see (5)) can be shared between d_a and d_b respectively as $\alpha_i C_{a_i}$ and $(1-\alpha_i)C_{a_i}$ with $\alpha_i \in [0,1]$. In a similar way every element of the set B_a (see (6)) can be shared between d_a and d_b respectively as $\beta_j B_{a_j}$ and $(1-\beta_j)B_{a_j}$ with $\beta_j \in [0,1]$. In this way it is possible to define the four sets:

$$C_1 = \{\alpha_i C_{a_i} \mid i \in I\} \tag{7}$$

$$C_2 = \{(1-\alpha_i) C_{a_i} \mid i \in I\} \tag{8}$$

$$B_1 = \{\beta_j B_{a_j} \mid j \in J\} \tag{9}$$

and:

$$B_2 = \{(1-\beta_j) B_{a_j} \mid j \in J\} \tag{10}$$

We remark how C_1 and B_1 are for d_a whereas C_2 and B_2 are for d_b and that the elements C_{a_i} and B_{a_j} are dimensional quantities not necessarily measured on commensurable scales so that it is hardly ever possible to merge them in a single numerical value through a weighted sum of some sort.
In the definitions (7), (8), (9) and (10) the meaningful parameters are represented by the coefficients α_i and β_j with their index sets I and J.
With these premises we have to specify the main features of:

(n_1) the coarse grain negotiation procedure,

(n_2) the fine grain negotiation procedure.

The former procedure, (n_1), involves heterogeneous items C_{a_i} and B_{a_j} and can be described as an heterogeneous barter ([1] and [4]) starting with the initial sets B_a and C_a.
The latter procedure, (n_2), involves homogeneous items represented by the parameters α_i and β_j and can be described as an homogeneous barter ([1]

and [4]).
We start with a discussion of (n_1) (see Figure 10) that involves **heterogeneous items**.
These heterogeneous items are the elements of the sets B_a and C_a that are the input data for the procedure that can involve:

(n_{1a}) a single [new] element,

(n_{1b}) multiple [new] elements from the same set,

(n_{1c}) multiple [new] elements from both sets.

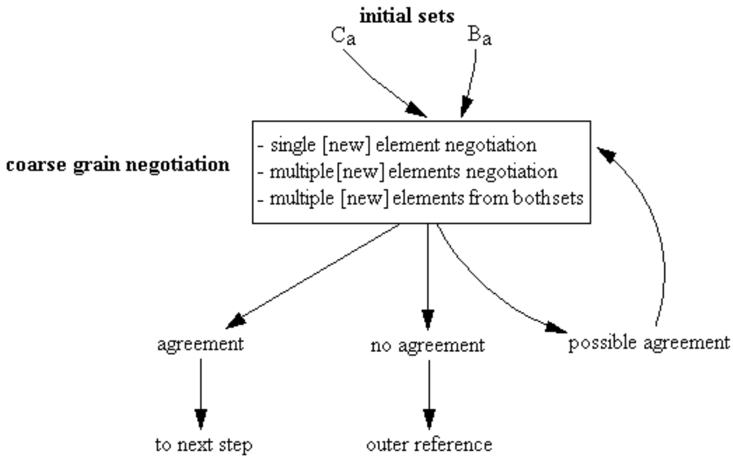

Figure 10: *Structure of the coarse grain negotiation procedure*

where the term $[new]$ identifies the elements with regard to the negotiation procedure.
At every step the players may perform a negotiation and then (see Figure 10):

$(s1)$ declare that they reached an **agreement**,

$(s2)$ declare that they did not reach an agreement but that there is still space for negotiating (**possible agreement**),

$(s3)$ declare that they did not reach an agreement and that there is no more space for negotiating (**no agreement**).

In the case $(s1)$ the players did agree on what to share so they have to negotiate on how to share it through a **fine grain negotiation**.

In the case ($s2$) they perform another negotiation step whereas in the case ($s3$) they resort to an outer authority that act as mediator (see also Figures 8 and 9).
The core of the procedure is represented by the mutually exclusive steps (n_{1a}), (n_{1b}) and (n_{1c}) that act on the sets B_a and C_a so to modify them by rising or lowering each of their elements.
Of course both players know that the coarse grain negotiation is followed by the fine grain negotiation so that they act so to either enlarge (benefits) or reduce (costs) the pie before sharing it.
With this we mean that both players have incentives for making untruthful declarations. At the very start of the negotiation d_a is favorable to i_a whereas d_b is an opponent to i_a. This means that, since d_a wants d_b accept i_a, he may exaggerate the benefits while, on the other hand, he may underestimate the costs. On the other hand at the very start d_b tends to behave in the opposite way. During the negotiation ([19]) both players tend to make each other concessions and to move towards middle point solutions.
At this point we analyze in some detail the **coarse grain** procedure and so (n_1).
The procedure involves the sets C_a (5) and B_a (6). These sets may contain:

- correlated quantities,

- independent quantities.

In the correlated case we have a subset of indexes $\hat{I}$ in common between I and J such that for all the index values $i = j \in \hat{I}$ there is a correlation between C_{a_i} and B_{a_j}.
Such correlations are shown in Figure 11.

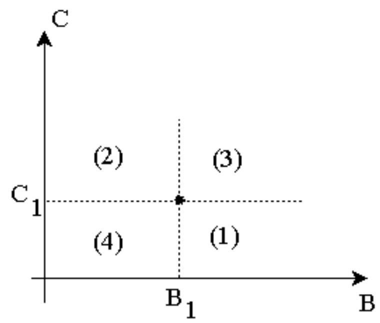

Figure 11: *Types of correlations between benefits and costs*

In Figure 11 we have that:

(1) and (2) denote zones where the correlation is of inverse type,

(3) and (4) denote zones where the correlation is of direct type.

In the independent case we have the subsets of indexes $\bar{I} = I \setminus \hat{I}$ and $\bar{J} = J \setminus \hat{I}$ that refer to elements that have no correlation. This means that in these cases we have:

- benefits without costs or with negligible costs or with constant costs;

- costs without benefits or with negligible benefits or with constant benefits.

At this point we can give a schematic description of the high level structure of one possible **coarse grain negotiation** algorithm in this case. We note that d_a presents the sets B_a and C_a and we can imagine that d_b responds in a similar way so that an acceptance is implicitly revealed by d_b by simply making an identical counterproposal.
The proposed algorithm has the following structure (where we use familiar conventions):

(1) d_a presents the sets B_a and C_a;

(2) d_b presents the sets B'_a and C'_a;

(3) we have the following cases:

  (3.a) if $B_a = B'_a$ and $C_a = C'_a$ then go to (4);
  (3.b) if $B_a \neq B'_a$ or $C_a \neq C'_a$ then:
    a. with a random device we define on ordering between the two players;
    b. the player who comes first in the ordering gets a token only if he declares he wishes to rethink about his proposal otherwise the token assignment procedure is repeated with the other player;
    c. if d_a has the token then:
      (i) d_a presents the modified sets B_a and C_a;
      (ii) go to (3);
    d. if d_b has the token then:
      (i) d_b presents the sets B'_a and C'_a;
      (ii) go to (3);
    e. if none of them has the token then go to (5);

(4) go to the **fine grain negotiation** algorithm;

(5) d_a and d_b agree to go on or to give up;

(6) if they go on then go to (1) else call outer mediator routine;

The steps (1) and (2) are made simultaneously by the two players so that none of them knows in advance the proposal made by the other but at the very first step when they are made in succession. The notations used at steps (3.a) and (3.b) are shorthands to denote, respectively, agreement and disagreement between the two deciders. The same holds in all similar cases. According to the algorithm the two players make concessions in turn ([19]), each player having the possibility to make consecutive concessions.
The random device may be the toss of a fair coin. Step (3.$b.e.$) means that both players enter in the deliberative phase of step (5). At this step both may decide that there is still space for concessions or they can declare that there is no more space for concessions so that the negotiation cannot go on. In the former case the algorithm goes back to steps (1) (and (2)), in the latter case the algorithm closes with a call to an outer mediation routine (see Figure 9).
As to the possible strategies of the two players we recall that:

- d_a wants i_a to be realized being its proponent;

- d_b does not want i_a to be realized being its opponent.

From this we may derive that d_a:

- emphasizes the elements of B_a;

- tries to reduce the weight of the elements of C_a;

- makes concessions to d_b under the form of further benefits.

The goal of d_a is of obtaining the assent of d_b on the composition of the two sets B_a and C_a in such a way that the **fine grain negotiation** can be structured so to allow to d_a to attain higher benefits and lower costs that d_b. On the other hand d_b behaves in almost the opposite way since he:

- emphasizes the elements of C_a;

- tries to reduce the weight of the elements of B_a;

- asks for concessions to d_a under the form of further benefits.

The goal of d_b is assenting to d_a on the composition of the two sets B_a and C_a in such a way that the **fine grain negotiation** can be structured so to allow d_b to attain higher benefits and lower costs that d_a.
In this framework the **coarse grain negotiation** starts from a disagreement between the two players that have no common co-operative ground ([19], [23]) as a basis to reach an agreement since, at least at the very start they do not agree either on the need to reach an agreement. Within this framework the negotiation starts with d_a making some concessions that d_b may judge either satisfactory or not. In the former case the negotiation is over whereas in the latter it is the turn of d_b to make requests and concessions to d_a that may either accept or refuse according to a scheme that we already showed.
As we have already seen, in the case $(s1)$ the two players are engaged in a **fine grain negotiation** ((n_2)). Such a negotiation involves the way in which the two players share the elements of the sets B_a and C_a so that it actually involves the set α of the coefficients $\alpha_i \in [0, 1]$ $(i \in I)$ and the set β of the coefficients $\beta_j \in [0, 1]$ $(j \in J)$.
From these premises we may classify this phase of negotiation as involving the **homogeneous items** of the sets α and β.
Also in this case we can give a schematic description of the high level structure of one possible negotiation algorithm.
The proposed **fine grain negotiation** algorithm has the following structure:

(1) d_a presents the sets α and β;

(2) d_b presents the sets α' and β';

(3) we have the following cases:

  (3.a) if $\alpha = \alpha'$ and $\beta = \beta'$ then go to (4);
  (3.b) if $\alpha \neq \alpha'$ or $\beta \neq \beta'$ then:
    a. with a random device we define on ordering between the two players;
    b. the player who comes first in the ordering gets a token only if he declares he wishes to rethink about his proposal otherwise the token assignment procedure is repeated with the other player;
    c. if d_a has the token then:
      (i) d_a presents the modified sets α and β;
      (ii) go to (3);
    d. if d_b has the token then:
      (i) d_b presents the sets α' and β';

(ii) go to (3);

e. if none of them has the token then go to (5);

(4) end;

(5) go back to the **coarse grain negotiation procedure**;

In this case the algorithm does not contains a call to an external routine of mediation since, at this stage, the two players can negotiate the sets α and β without the need of an outer intervention that may be necessary at the coarse grain stage where they do not agree on what they have to share.
Also in this case the random device may be the toss of a fair coin. Step (3.*b*.*e*.) means that both players declare that there is no more space for concessions so that the negotiation cannot go on.
In this case we are in a phase where the players agreed on what to share and must find an agreement on how to share it. In this phase we can imagine ([19], [23]) that both players try to maximize benefits and minimize costs taking into account that too strongly exploitative attitudes may prevent the reaching of any agreement.
At this stage we may imagine that both players have an interest in concluding the agreement so that each of them avoids to exploit excessively the other.
The structure of the algorithm we have shown before can be modified to take into account that each player has an interval of acceptability for every parameter of the sets α and β. If we consider d_a (but the same is true also for d_b) we have:

$[\alpha_{i_{min}}, \alpha_{i_{Max}}]$ for every $\alpha_i \in [0, 1]$ and $i \in I$;

$[\beta_{j_{min}}, \beta_{j_{Max}}]$ for every $\beta_j \in [0, 1]$ and $j \in J$.

We note how the negotiation can proceed either with each player starting either with average values or trying to secure one of the parameter at either the maximum (benefit) or minimum (cost) value being sure that the other will act in the same way over another parameter rather than contesting his choice on that parameter.

5.2 Double negotiation procedures

In this section we present the abstract structure of the negotiation in the case ($c2$) where the representative players d_a and d_b present an issue each, i_a and i_b respectively. The abstract structure of the negotiation process is shown in Figure 12.
We recall that the issue i_a is associated with the two sets (B_a, C_a) and the

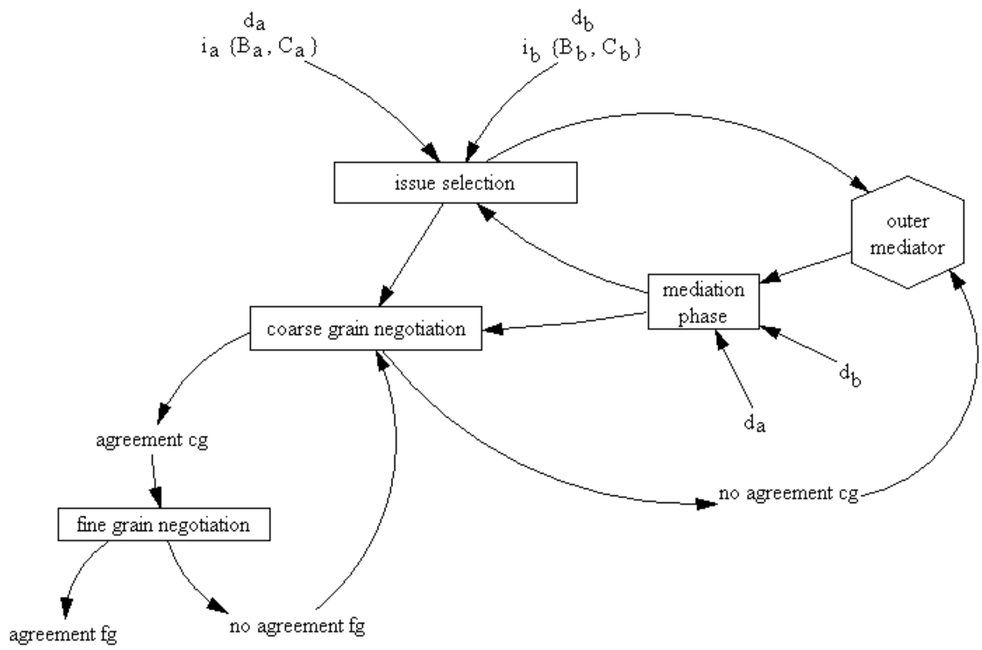

Figure 12: *Structure of the double negotiation procedures*

issue i_b is associated with the two sets (B_b, C_b) of benefits and costs. Both players know this and know that every player know this and so on. This means that these data are common knowledge between the players ([16], [17] and [18]).
In Figure 12 we show the main building blocks of the procedure. For what concerns the inner structure of both the **coarse grain negotiation** module and the **fine grain negotiation** module we refer to section 5.1.
In this section, therefore, we have only to deal with the **issue selection** module and the roles of the **outer mediator** in the two cases:

(m_1) as an **issue selection helper**,

(m_2) as a **coarse grain negotiation helper**.

In the role (m_1) the outer mediator tries to have the two players agree on which issue they have to deal with at that stage. The selection can be made either using an agreed on random device for the selection of one of the two issues or having the mediator choosing it according to criteria that he defines but that both players accept. In the latter case the mediator should be able

to argument about his decision upon request of one of the two players or both. Such argumentation can be judged either satisfactory or unsatisfactory: in the latter case the mediator must either revise his arguments (so that the procedure is repeated) or can concede that the selected issue should be the previously discarded one.
In any way at each stage both players know that there is another possible alternative to be checked if there is no possibility of agreement on the currently examined issue.
In the role (m_2) the outer mediator tries to have the two players agree on the inner structure of the benefits and costs sets of the issue they are considering at that stage.
It is easy to understand how the mediator plays a key role in the process so that he must be appointed by both players, have and keep their confidence and being recognized as satisfying requirements of **neutrality**, **impartiality** and **fairness**.
We remark that:

- the requirement of **neutrality** turns into a behavior that is devoid of any open or hidden support of one of the two players in their interactions;

- the requirement of **impartiality** concerns the unbiased attitude of the mediator with regard to the proposals and the counter proposals of the players;

- the requirement of **fairness** concerns the decisions taken by the mediator that must be seen by the players as being taken on objective bases in the sense that they can be deduced/inferred and justified.

One way to enforce **impartiality** is to have the mediator acting in a Delphi like setting ([8], [11]) and so working on documents made anonymous so to be focused on their content without any bias from the identity of the presenter.
On the other hand both **neutrality** and **fairness** must be recognized explicitly by both players so that if one of them casts any doubt on the mediator about these features either he is able to justify his conduct or the players must engage in the selection of a new mediator.
We note, indeed, that the selection of the mediator can be carried out by using a consensual procedure such as the following ([5]):

(1) with a random device we select one of the two players, be it 1;

(2) 1 may propose a new name or pass;

(3) if 1 proposes a name then

   (i) 2 may accept then go to (5);

   (ii) 2 may refuse so that 1 and 2 exchange their roles and go to (2);

(4) if 1 passes then

   (iii) 2 may pass and go to (5);

   (iv) 2 proposes a new name, 1 and 2 exchange their roles and go to (3);

(5) end;

We remark how 1 can be either d_a or d_b depending on the outcome of the random selection whereas 2 is either d_b or d_a. The term **new** identifies a name that has never been proposed and rejected before.
At the step (*iii*) we can have two cases. In the former case both players pass but no name has ever been made so that no mediator is chosen, at least at this stage. In the latter case at least one name has been proposed so that this name identifies the chosen mediator.
We underline how the procedure for the selection of a mediator may be executed at any time during a negotiation both in the presence of an already chosen mediator or in the absence of any mediator but only upon an agreement from both players.
As we have shown in Figures 9 and 12 the figure of the mediator is a key figure in the proposed procedures so that whenever it is needed but is absent the players should be better off in trying to identify a trusted person and fill the role.

6 The possible extensions

The possible extensions are of two types. Those of the former type are common to both models whereas those of the latter types depend on the involved model.
The common extensions include:

(1_c) the abandonment of the concept of equivalent player so to describe the interactions between the two structured sets of competing deciders;

(2_c) the introduction of a reactive environment under the form of both stakeholders and experts;

(3_c) a richer mediation process with the involvement of further categories of mediators and experts;

(4_c) the refinement of both the coarse grain and the fine grain negotiation phases.

The extensions that involve only the **single project case** include:

(1_1) the introduction in the process of stakeholders as supporters and opponents to the single project;

(2_1) the similar introduction of experts with analogous policies but distinct roles;

(3_1) the introduction of electoral tools for either the approval or the rejection of the project.

The extensions that involve only the **double project case** include:

(1_2) the introduction in the process of stakeholders as supporters and opponents to both projects;

(2_2) the similar introduction of experts with analogous policies but distinct roles;

(3_2) the introduction of choice procedures directly involving the stakeholders in cases where the decision process has reached a stalemate;

(4_2) the extension of the model to more than two competing projects.

The last point (4_2) represents a critical point since complex procedures tend, in many cases, to perform poorly when the number n of the involved parties tend to grow too much. In practical cases, however, the number of the competing projects hardly ever is greater than 3 or 4.
The main aims of such extensions are the enrichment of both models so to increase their plausibility and their conformity to real world cases without, however, making the models too complex.
Whenever the models become too complex, indeed, they are harder to understand and accept from their users.
Too complex models tend, indeed, to focus the attention of their users on the models themselves distracting such users from the reality that each model aims at describing and analyzing.

7 Concluding remarks and future plans

This paper represents a tentative to analyze the dynamics through which one project may be imposed from its supporters so that its benefits and costs are shared in acceptable, or fair, ways among the involved deciders.
The analysis is at its beginning and needs refinements and study, including the extensions we have listed in section 6. Its main aim is the formalization, from both a descriptive and a normative perspective, of the decision processes in presence of a competition where the competitors aim at reaching an all-win solution through the sharing of costs and benefits.

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